Progress in physics relies heavily on increasing the precision of our statements about physical phenomena. Otherwise it would be impossible to identify yet uncharted areas of research or scrutinize experimental findings. Our research project's aim is a deeper, more precise understanding of the basic theory of elementary particles, known as the Standard Model of particle physics. Using the new insights that we expect to obtain, we shall be able to study possible extensions of this model in a particular part of the theory involving neutrino particles with yet unprecedented predictive power.

We know already much about the Standard Model. It comprises three of the four known basic interactions, while gravity is still out of correct quantum description. The Standard Model determines a definite number of elementary particles. In 2012, it proved to be finally consistent by the discovery of a scalar particle: the Higgs boson, found at the Large Hadron Collider (LHC) at CERN. The search for this elusive particle was strongly guided by precise calculations derived from the Standard Model. Similarly, in order to recognize signatures of New Physics, one has to understand the well-known Standard Model with absolute safety in the actual set-up. This is exactly a place where we operate.

Technically, we consider concepts taken from complex analysis and formulated by mathematicians R. H. Mellin and E. W. Barnes at the turn of 20th century. Their method of integral representations on complex plane offers a way to solve many classes of Feynman integrals that describe scattering processes of quantum particles, in particular higher-order perturbative effects. We are developing suitable methods and algorithms, and implement them to make predictions of subtle quantum effects which can be tested experimentally.

In the project we plan to focus on precise calculation of the Standard Model tiny effects connected with the Z-boson decay at resonance. It was one of the most important decays already at LEP (Large Electron-Positron collider) at CERN where millions of such events were observed. We would like to accomplish the calculation of Standard Model effects at the three-loop order of perturbative Quantum Field Theory, the so-called next-to-next-to-next-to leading order (NNNLO). This gigantic level of accuracy gives corrections to physical electroweak observables at the higher than per mil level. Such corrections are sensitive to the masses of the top quark, the gauge bosons $W^{\pm}, Z^0$, the Higgs boson, and potentially, new virtual states of matter which goes beyond the Standard Model. Then, there is no wonder that Z-boson resonance is considered as an option in future colliders. One of such precision machines is the so-called Future Circular Collider (FCC) in its electron-positron mode (FCC-ee). In FCC-ee huge statistics is foreseen (10^{12} of Z-boson decays), what makes possible to look at very rare events where New Physics effects can be detected. Here we will merge precise results with searching for traces of new particles, namely heavy neutrinos. These neutrinos are a part of many models which try to explain masses of known, light neutrinos lying at the heart of electroweak interactions. The issue of extracting information on new effects in neutrino physics which may include non-standard neutrino states is one of the hot topics in contemporary particle physics. This knowledge is of paramount importance for progress also in astrophysics and cosmology of Big Bang, leptogenesis and baryogenesis, dark matter.

The research undertaken is complex and made in cooperation with renowned scientists from USA, Germany, France and Spain. In this way, also local particle group in Poland will be strengthened considerably by work in demanding international environment and will have a chance to sustain a high level of basic research studies.